# Responses of woodland caribou (*Rangifer tarandus caribou*) to clear-cutting in east-central Newfoundland

TONY E. CHUBBS[1] AND LLOYD B. KEITH
*Department of Wildlife Ecology, University of Wisconsin, Madison, WI 53706, U.S.A.*

SHANE P. MAHONEY
*Newfoundland–Labrador Wildlife Division, Government of Newfoundland and Labrador, Box 8700, St. John's, Nfld., Canada A1B 4J6*

AND

MICHAEL J. MCGRATH
*Newfoundland–Labrador Wildlife Division, Government of Newfoundland and Labrador, Box 455, Clarenville, Nfld., Canada A0E 1J0*

Received May 27, 1992
Accepted October 28, 1992

CHUBBS, T. E., KEITH, L. B., MAHONEY, S. P., and MCGRATH, M. J. 1993. Responses of woodland caribou (*Rangifer tarandus caribou*) to clear-cutting in east-central Newfoundland. Can. J. Zool. **71**: 487–493.

Movements, sex and age structure, and habitat selection of adult woodland caribou (*Rangifer tarandus caribou*) were examined in relation to clear-cutting on summer range in east-central Newfoundland during 1987–1990. We obtained 2473 locations of 35 radio-collared caribou during at least two consecutive summers. Locations relative to clearcuts were determined for eight males and 27 females. Distances to existing clearcuts were compared with distances to those same geographic points prior to and following the summer in which clear-cutting occurred. Four males and 10 females maintained similar mean distances from clearcuts, 3 males and 12 females were farther away, and 2 females were closer. Three other females and one male were assumed to be too distant to be affected by clear-cutting. Of those found farther away from clearcuts, females were 2–3 times farther away than males. Among female caribou that maintained similar mean distances to clearcuts, habitat use during clear-cutting was similar to that before and afterwards. Females displaced by clear-cutting avoided open burns and hardwoods and selected mature black-spruce forest, whereas prior to cutting they used habitats in proportion to their availability. Sex and age ratios indicated that significantly fewer females and calves were present near clearcuts than elsewhere in the study area. Our results demonstrate that clear-cutting mature forests on summer range may affect the movements and distribution of woodland caribou.

CHUBBS, T. E., KEITH, L. B., MAHONEY, S. P., et MCGRATH, M. J. 1993. Responses of woodland caribou (*Rangifer tarandus caribou*) to clear-cutting in east-central Newfoundland. Can. J. Zool. **71** : 487–493.

Les déplacements, la répartition des sexes, la distribution des âges et le choix des habitats chez des adultes du Caribou des bois (*Rangifer tarandus caribou*) ont été mis en relation avec la coupe à blanc sur leur aire d'été dans le centre-est de Terre-Neuve en 1987–1990. Trente-cinq caribous, 8 mâles et 27 femelles, porteurs d'émetteurs-radio à collier ont été repérés à 2473 reprises sur au moins deux étés consécutifs. Les distances entre la position des animaux et les zones de coupe à blanc ont été mesurées. Les positions des animaux par rapport aux sites de coupe ont pu être comparées un an avant et un an après la coupe. Quatre mâles et 10 femelles n'ont pas changé leur position vis-à-vis les zones de coupe, 3 mâles et 12 femelles s'en sont éloignés et 2 femelles s'en sont rapprochées. Les 3 autres femelles et l'autre mâle étaient probablement trop loin pour être affectés par la coupe. Parmi les animaux qui s'étaient distanciés de la zone de coupe, les femelles s'en étaient éloignées de 2 à 3 fois plus que les mâles. Les femelles qui n'avaient pas changé de position continuaient à exploiter les mêmes habitats qu'avant la coupe. Cependant les femelles, qui avaient modifié leur position, évitaient les brûlis ouverts et les zones de bois durs pour se concentrer dans les forêts matures d'Épinette noire, alors qu'avant la coupe elles utilisaient tous ces habitats en proportion de leur disponibilité. Significativement moins de femelles et de petits se retrouvaient aux abords des zones de coupe qu'ailleurs sur le terrain étudié. La coupe à blanc de forêts matures sur l'aire d'été du Caribou peut donc affecter les déplacements et la répartition des animaux.

[Traduit par la rédaction]

## Introduction

Much of the historical range of caribou in North America has experienced some form of industrial activity, primarily timber harvest, mining, and oil and gas development. Numerous studies have dealt with the responses of barren ground (*Rangifer tarandus granti*), tundra (*R. t. groenlandicus*), and woodland caribou (*R. t. caribou*) to: (*i*) man-made structures (Miller *et al.* 1972; Hanson 1981; Johnson and Todd 1977); (*ii*) sensory disturbances (Lent 1964, 1966; Miller and Gunn 1979; Horejsi 1981), and (*iii*) petroleum-related development (Klein 1971; Cameron *et al.* 1979; Curatolo and Murphy 1986; Whitten and Cameron 1983; Smith and Cameron 1985; Murphy and Curatolo 1987).

There is little information on the effects of forest clear-cutting on the distribution of woodland caribou. Darby and Duquette (1986) provided the first evidence for displacement of woodland caribou by clear-cutting: two of three caribou–forestry interactions in northern Ontario resulted in the apparent disappearance of caribou from peripheral sections of winter range. Aerial transect surveys revealed that caribou did not occupy clearcuts but were found in adjacent mature and overmature conifer forests. Cumming and Beange (1987) suggested that dispersing caribou in southern Ontario may have been displaced from former wintering areas by logging.

[1]Present address: Newfoundland–Labrador Wildlife Division, Government of Newfoundland and Labrador, Box 488, Station C, Goose Bay, Labrador, Canada A0P 1C0.

Printed in Canada / Imprimé au Canada

Woodland caribou in boreal forests of North America use mature and overmature spruce (*Picea* spp.) and pine (*Pinus* spp.) stands extensively (Shoesmith and Storey 1977; Fuller and Keith 1981; Darby and Pruitt 1984; Edmonds and Bloomfield 1984; Brown *et al.* 1986; Edmonds 1988; Rominger and Oldemeyer 1989). Woodland caribou of the Middle Ridge and Mount Peyton herds in east-central Newfoundland mostly inhabit the boreal forest during summer, and winter 40–60 km south on the coastal barrens (McGrath 1987)[2]. The harvest of mature softwoods, primarily for pulp production, has occurred on the summer range of this herd for the past decade (McGrath 1987)[2].

The primary aim of our study was to determine the effect of clear-cutting mature forests on the distribution of Middle Ridge caribou during summer. Specifically, we wished to determine changes in movements, sex and age structure, and habitat selection relative to cutting and related disturbances.

## Methods

*Study area*

The Northwest Gander – Gull Lake region of east-central Newfoundland (Fig. 1) is a heavily forested area with gentle relief and an average elevation of 250 m (Roberts 1983). Local variations in topography are the result of ice scour and glacial deposits. Phytogeographically, this region belongs to the Central Newfoundland Ecoregion (Damman 1983), a subdivision of the Northern Boreal Zone. Forests of balsam fir (*Abies balsamea*) with dense moss carpets of *Hylocomium splendens* (Damman 1964) occupy the zonal soils and predominate in southern regions undisturbed by fire during the last century. Sheep-laurel (*Kalmia angustifolia*) – black spruce (*Picea mariana*) forests dominate the northern regions, and *Pleurozium* – balsam fir forests are common in the south. White birch (*Betula papyrifera*) is common throughout, and trembling aspen (*Populus tremuloides*) stands occur locally. Dwarf-shrub heath dominated by sheep-laurel, and to a lesser extent Labrador tea (*Ledum groenlandicum*), occur locally on nutrient-poor parent materials. Raised bogs with irregular concentric rings of pools are common. Scattered low black spruce and larch (*Larix laricina*) trees usually occur on the bogs (Damman 1983). Lakes, ponds, and streams are numerous, and barrens (heath and bog) are extensive.

This region has cool, wet summers and cold winters. The mean daily temperature ranges from 16°C in July to −7°C in February. Total annual precipitation (water equivalent) averages 135 cm, with measurable precipitation occurring on 175–200 days. Snowfall averages 300 cm annually and occurs from late November to late April (Banfield 1983).

Our work was conducted primarily within the 2650-km² Northwest Gander Study Area (NWGSA), defined by a Landsat thematic image (NORDCO Ltd., St. John's, Newfoundland). Abitibi-Price Company Ltd. has based clear-cutting operations in the northern portion of this area since 1981, harvesting primarily black spruce and balsam fir for pulp production, and secondarily white birch and aspen for lumber. These operations resulted in the construction of a main road that extends 43 km eastward from the Bay D'Espoir Highway towards Newton Lake, and a network of side roads (Fig. 1). These roads are collectively referred to as the Northwest Gander Road System (NWGRS). The extreme northern portion of the study area, known as the Caribou Lake Road System (CLRS), was clear-cut prior to 1982. Clearcuts within the study area since 1986 totalled 21.1 km² in 1987, 13.2 km² in 1988, 10.9 km² in 1989, and 10.8 km² in 1990. Cutting occurred during 15 May–15 November 1987, 1 June–30 November 1988, 5 July–1 November 1989, and 31 July–21 December 1990.

The study area is utilized during summer by two main woodland caribou herds: the Mount Peyton and the Middle Ridge, estimated to

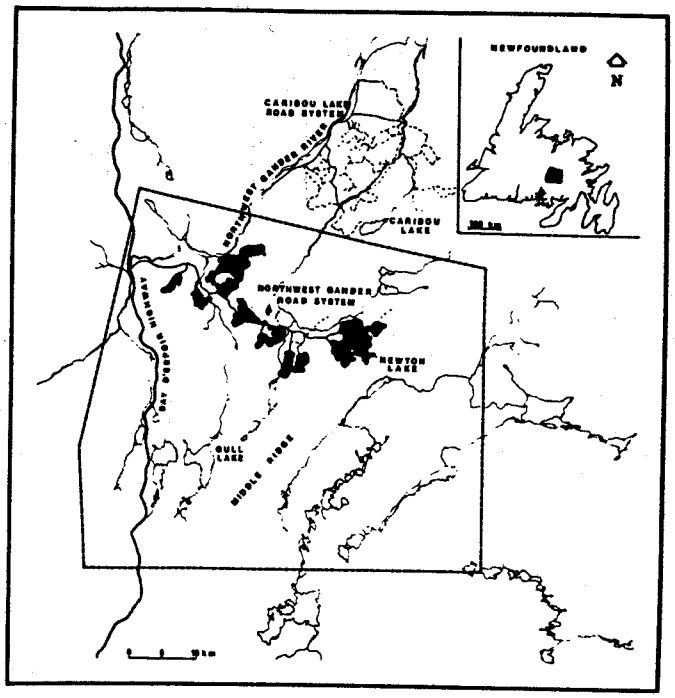


FIG. 1. The Northwest Gander Study Area (NWGSA) in east-central Newfoundland showing clearcuts as shaded regions and forest access roads as dashed lines.

contain a combined population of 13 000 – 15 000 animals. The population is lightly hunted and currently growing (S. P. Mahoney personal communication). The northern half of the study area is easily accessed by road; the southern portion is accessible only by air.

Besides man, predators of caribou within the study area include black bears (*Ursus americanus*), which are relatively common, and lynx (*Lynx canadensis*), which are relatively scarce. Wolves (*Canis lupus*) were extirpated from insular Newfoundland by the early 1900s (Allen and Barbour 1937). The only other cervids present are moose (*Alces alces*), which were successfully introduced into Newfoundland in 1904.

*Capture and radio-collaring*

We captured and radio-collared 69 caribou ≥1.5 years old during June–August of 1987–1990. Caribou were selected to obtain a sex ratio similar to that observed on their winter range. Five females collared prior to 1987 during a pilot study were also monitored during our study. Of the 74 caribou radio-collared, only 35 (27 females and 8 males) yielded sufficient data for our analyses.

Initially, caribou ($n$ = 43) were darted from a Bell 206L helicopter (4–10 June 1987) during the calving period. These animals were captured on their summer range near the NWGRS, prior to the commencement of cutting activities. During 1988–1990, caribou ($n$ = 31) were darted from the ground to minimize stress and chances of capture myopathy (Valkenburg *et al.* 1983). They were immobilized with xylazine hydrochloride (5–6 mg/kg body weight) via Cap-Chur projectile darts (Palmer Chemical and Equipment Co., Douglasville, Ga.), and fitted with mortality sensing radio collars (Lotek Engineering Inc., Aurora, Ont.) transmitting at 149–151 MHz.

*Radiotracking*

Radio-collared caribou were relocated (Mech 1983) every 3–5 days during June–September using a Cessna 185 equipped with strut-mounted directional antennae (Telonics, Inc., Mesa, Ariz.). On average, radio-collared caribou were relocated 22 times (range 10–40) per summer. We also used a Bell 206L helicopter to locate radio-collared females during the calving period (30 May–7 June) to assess their reproductive status. Coordinates of individual caribou were recorded to the nearest 0.01 minute using LORAN-C (Boer *et al.* 1989)

[2]M. J. McGrath. 1987. Effects of logging on woodland caribou (*Rangifer tarandus caribou*) in central Newfoundland. Unpublished report, Department of Environment and Lands, Newfoundland and Labrador Wildlife Division, St. John's, Newfoundland.

TABLE 1. Summer habitat use versus availability for female woodland caribou before, during, and after clearcutting within the Northwest Gander Study Area (NWGSA), 1987–1990

| Habitat category | Area | | % habitat use where mean distance from clearcuts: | | | | |
|---|---|---|---|---|---|---|---|
| | | | remained the same ($n$ = 10) | | | increased ($n$ = 10)[a] | |
| | km² | % of total | Before cut | During cut | After cut | Before cut | During cut |
| Barrens–bog[b] | 836 | 33.4 | 42.3 | 37.9 | 35.3 | 41.0 | 37.7 |
| Softwood shrub[c] | 592 | 23.7 | 20.1 | 25.6 | 21.2 | 22.2 | 20.0 |
| Black spruce[d] | 445 | 17.8 | 19.6 | 22.0 | 18.2 | 19.4 | 28.0[e] |
| Burned[f] | 296 | 11.8 | 7.2 | 5.3[e] | 12.4 | 8.3 | 4.6[g] |
| Dead softwood[h] | 190 | 7.6 | 6.2 | 4.8 | 4.1 | 6.9 | 6.3 |
| Hardwoods[i] | 86 | 3.4 | 2.1 | 1.8 | 4.1 | 2.1 | 1.1[g] |
| Clearcut[j] | 56 | 2.2 | 2.6 | 2.6 | 4.7 | 0.0 | 2.3 |
| Number of locations | | | 194 | 227 | 170 | 144 | 175 |

NOTE: Excluded from calculations were 149 km² of water that were considered unavailable.
[a] Analysis for following year not shown ($n$ = 2).
[b] *Kalmia* barrens and *Scirpus–sphagnum* bog.
[c] *Picea mariana* and *Abies balsamea* ≤3 m.
[d] Mature *P. mariana*.
[e] Used more ($P \leq 0.05$) than expected.
[f] All habitat categories burned in 1986.
[g] Used less ($P \leq 0.05$) than expected.
[h] Dead *A. balsamea* and *P. mariana*.
[i] *Betula papyrifera* and *Alnus* spp.
[j] *P. mariana* cut during 1987–1990.

at 1000–2000 m altitude, and later converted into UTM coordinates. To verify the precision of the LORAN-C unit, we periodically checked the position of the aircraft relative to known ground reference points (e.g., bridges, road intersections, and topographic features). The accuracy of LORAN-C fixes for radio collars was determined in 1990 by relocating eight transmitters placed at known UTM locations within the study area. The mean error of our radio locations was thereby estimated as a circular area 200 m in radius. One hundred and eighteen flights were made during 1987–1990, providing 2473 individual locations of radio-collared caribou.

*Classifications*

Caribou were classified as adult males, adult females, or calves from the ground or helicopter. Ground classifications were made along the NWGRS from June to September throughout 1987–1990 using a window- or tripod-mounted spotting scope (60-power) or 10 × 50 binoculars. All animals encountered were classified, and possible repeat observations (i.e., those several hours apart but involving groups of similar composition and location) were noted. Aerial classifications were conducted within the CLRS during July and August, 1988–1990, and yearly on the herd's winter range during October or November beginning in 1984, by the Newfoundland and Labrador Wildlife Division. Repetitive sampling during aerial classifications was minimized by discounting those animals thought to have been previously observed.

*Habitat composition*

Habitat composition was determined through digital analysis of a satellite image acquired by a Landsat Thematic Mapper sensor on 31 July 1987. Landsat data were analyzed at NORDCO Ltd., St. John's, Newfoundland, using an ARIES III Image Analysis System implemented on a Vax II/750 computer. A supervised maximum-likelihood classification (Afoldi 1978) was performed on the image, and 16 habitat classes were identified. We combined classes with similar vegetation characteristics into seven terrestrial habitat types (Table 1). Habitat alterations due to clear-cutting since 1987 were digitized and superimposed on the Landsat image using SEAS (Spatial Ecology Analysis System; J. Cary, University of Wisconsin, Madison, Wis.) software for analysis of habitat availability, habitat use, and animal movements.

*Statistical analysis*

To assess the effect of capture methods on the subsequent movement of radio-collared caribou, we compared the mean movement rate between capture and first relocation with that between first and second relocation. These two rates averaged 1.36 and 1.38 km/d respectively ($P$ = 0.95). We thus assumed that caribou movement rates were unaffected by capture.

Caribou locations were analyzed for changes in caribou distribution relative to the nearest recent clearcuts and in patterns of habitat use. Habitat availability did not differ significantly between years because clearcuts accounted for just 2.2% of the total study area.

We compared the estimated distances of individual animals from the center of the closest active cut with distances from that same point during (*i*) the summer prior to cutting (when the area was mature forest) and (*ii*) the summer following cutting. The centers of clearcuts (center of mass) were used in our analysis since cuts increased in size throughout the summer through ongoing cutting. Individual caribou were categorized among years as having an increased, decreased, or similar mean distance to the nearest clearcut center, relative to distances during both the previous and subsequent summers.

We calculated harmonic-mean centers of activity (Dixon and Chapman 1980) for the 4 caribou (3 females, 1 male) that were farthest from clearcuts. These animals averaged ≥15 km from the nearest clearcut and were thus assumed to be unaffected by clearcutting. Distances between activity centers were compared between summers to determine the annual variation in mean location and to assess the summer range fidelity of undisturbed caribou.

We compared the habitat use of female caribou that moved away from clearcuts with those that did not. All habitats within the study area were considered equally available. Preference or avoidance of individual habitats was determined using $\chi^2$ analysis and Bonferroni $z$-statistics (Neu *et al.* 1974). If habitats were used significantly ($P \leq 0.05$) more or less than they were available, we considered them preferred or avoided, respectively. This analysis was restricted to females because male sample sizes were too small ($n$ was less than the number of habitat categories) for meaningful analyses (Alldredge and Ratti 1986). Data were pooled across individuals because analyses at the individual level indicated similar habitat-use patterns (White and Garrott 1990). We used independent $t$-tests (Zar 1984) to

TABLE 2. Mean distance of radio-collared adult woodland caribou from the nearest clearcut in the Northwest Gander Study Area (NWGSA), 1987–1990

| Sex | $n^a$ | Significant increase in distance | Mean distance to center of nearest clearcut (km) | | | | |
|---|---|---|---|---|---|---|---|
| | | | Summer before cut | $P^b$ | Summer during cut | $P^b$ | Summer after cut |
| Male | 4 | No | 9.6 (5.0–15.9) | 0.32–0.76 | 11.4 (5.5–17.2) | 0.39–0.84 | 9.8 (5.9–16.1) |
| | 3 | Yes | 9.2 (8.2–10.2) | 0.01–0.03 | 12.9 (9.5–14.7) | 0.00–0.01 | 15.1 (10.4–19.7) |
| Female | 10 | No | 9.8 (4.5–14.0) | 0.09–0.81 | 10.0 (6.7–13.6) | 0.06–0.67 | 11.1 (7.3–16.0) |
| | 10 | Yes | 10.6 (2.8–16.9) | 0.00–0.03 | 20.8 (6.4–43.7) | | |
| | 2 | Yes | | | 12.7 (10.5–14.8) | 0.01–0.02 | 17.0 (16.0–18.0) |

NOTE: Range of mean distances for individual caribou shown in parentheses.
[a]Animals with ≥10 locations per summer.
[b]Range of $P$ values comparing distances for individual caribou between successive summers, 1987–1990.

compare sex ratios observed near clear-cuts with ratios observed in other regions of the study area.

## Results

### *Caribou locations relative to clearcuts*

From individual radio locations we determined the mean distance to the nearest clearcut for eight adult-male and 27 adult-female caribou during the summers of 1987–1990 (Table 2). The mean distances of four males and 10 females did not change significantly ($P$ range, 0.06–0.84). The mean distances for three other males and 10 females increased during the summer of clear-cutting, whereas the mean distances for two females decreased.

Mean distances prior to clear-cutting were similar among males and females (Table 2). Those that moved farther from clearcuts did so mainly during the summer that cutting took place rather than during the following summer. Within this group, females ($n$ = 10) were an average of 10.2 km farther away during the summer of cutting. Males ($n$ = 3) increased their mean distance an average of 3.7 km during, and an additional 2.2 km after, summers of cutting. Thus, females appeared more sensitive to disturbance, moving two to three times farther than males. Each of the four animals outside the NWGRS that we considered too distant (≥15 km) to be affected by clear-cutting maintained activity centers within an average radius of 2.2 km over all 4 summers.

### *Habitat use*

Habitat use differed between female caribou that moved away from clearcuts versus those that did not (Table 1). The latter used all habitats in proportion to availability during summers before and after cuts were made. During the summer of cutting, however, open burned areas were avoided: 5.3% of radio locations occurred in the 11.8% of the study area that was burned. On the other hand, black-spruce forest was used somewhat more frequently than expected on the basis of its availability: 22.0% versus 17.8%, respectively.

In summers before cutting, females whose mean distance increased during clear-cutting used all habitats in proportion to their occurrence (Table 1), but during cutting they preferentially selected mature black-spruce stands: 28.0% of radio locations occurred there whereas such stands accounted for only 17.8% of the study area. In contrast, open burns and hardwoods were used disproportionately less: 4.6 and 1.1%, respectively, of radio locations were obtained on the burned (11.8%) and hardwood (3.4%) habitat.

TABLE 3. Sex and age classification of woodland caribou near the Northwest Gander Road System (NWGRS) during June–September, 1987–1990

| Year | Adults: no. of males per 100 females | No. of calves per 100 females |
|---|---|---|
| 1987 | 298 (366) | 15 (92) |
| 1988 | 247 (238) | 24 (68) |
| 1989 | 193 (1011) | 22 (345) |
| 1990 | 158 (510) | 21 (198) |
| Mean | 224 | 21 |
| Total | (2125) | (703) |

NOTE: Number of adults shown in parentheses.

### *Sex and age ratios*

Classifications within our study area where cutting was taking place yielded abnormally high adult male:female ratios, and low calf:cow ratios. Male:female ratios averaged 224:100 near the NWGRS during 1987–1990 (Table 3), but just 53:100 ($P$ < 0.01) on old cuts (near the CLRS) and 53:100 ($P$ < 0.01) on the Middle Ridge wintering grounds (Tables 4 and 5). Mean calf:cow ratios near the NWGRS (21:100) were somewhat lower ($P$ = 0.17) than near the CLRS (29:100), and much lower ($P$ < 0.01) than on the Middle Ridge wintering grounds (43:100).

## Discussion

To the best of our knowledge, this study provides the first assessment of the impacts of forest clear-cutting on the movements, sex and age structure, and habitat selection of woodland caribou during summer. Other studies of human disturbance, particularly the effects of oil exploration and development on wild *Rangifer* populations in North America, have concentrated on barren ground caribou: *R. t. granti* in Alaska, and *R. t. groenlandicus* and *R. t. pearyi* in the Yukon and the Northwest Territories.

### *Movements*

Changes in caribou movements have frequently been related to human activity (Klein 1971, 1980, 1991; Banfield 1974; Curatolo 1975; Curatolo and Murphy 1986). Other studies have examined the responses of barren-ground caribou to man-made barriers (Miller *et al.* 1972). Avoidance of portions of traditional summer and winter ranges by barren ground caribou in Alaska has been attributed to disturbance from highway traffic and to activities associated with pipeline construction (Roby

TABLE 4. Sex and age classification of woodland caribou near the Caribou Lake Road System (CLRS) during July–August, 1988–1990

| Date | Adults: no of males per 100 females | No. of calves per 100 females |
|---|---|---|
| 8 August 1988 | 38 (90) | 34 (65) |
| 26 July 1989 | 36 (102) | 32 (75) |
| 4 July 1990 | 68 (94) | 14 (56) |
| 9 August 1990 | 70 (121) | 35 (71) |
| Mean | 53 | 29 |
| Total | (407) | (267) |

NOTE: Number of adults shown in parentheses.

TABLE 5. Sex and age classification of woodland caribou on the Middle Ridge wintering grounds during October or November, 1984–1990

| Date | Adults: no. of males per 100 females | No. of calves per 100 females |
|---|---|---|
| 14 October 1984 | 50 (412) | 53 (274) |
| 19 October 1985 | 71 (523) | 46 (305) |
| 18 October 1986 | 65 (686) | 42 (415) |
| 15 November 1987 | 52 (544) | 46 (358) |
| 15 October 1988 | 50 (538) | 46 (358) |
| 18 October 1989 | 41 (759) | 40 (538) |
| 10 October 1990 | 43 (727) | 26 (510) |
| Mean | 53 | 43 |
| Total | (4189) | (2758) |

NOTE: Number of adults shown in parentheses.

1978; Miller and Gunn 1979; Cameron *et al.* 1979; Cameron and Whitten 1980; Horejsi 1981), and is reportedly accentuated in areas of intense activity (Smith and Cameron 1983).

The present study indicated that about half of the 31 radio-collared caribou initially within 15 km of clearcuts during summer moved away from clear-cutting and (or) related disturbances; whereas only two moved nearer. Caribou at distances $\geq 15$ km maintained similar centers of activity during the 4-year study period. On average, females and males increased their mean distance from ongoing clearcuts by 10.2 km and 3.7 km, respectively.

Avoidance of clearcuts in the NWGSA appeared to be mainly a response to ongoing operations and not to past clearcuts as such. However, caribou that were displaced by clear-cutting apparently continued to increase their mean distance from clearcuts during the following summer: females by 4.3 km, males by 2.2 km. Caribou elsewhere have been observed to "avoid" disturbed areas well after the initial disturbance ceased (Cameron *et al.* 1979).

Caribou that did not shift their summer ranges may have habituated to activity associated with clear-cutting. Such habituation may depend upon the duration or level of disturbance. Bergerud (1974), for example, stated that caribou could habituate rather rapidly to repetitive stimuli, depending upon their severity. Valkenburg and Davis (1985) reported that the Delta Caribou Herd in Alaska had habituated to aircraft overflights, and for the most part did not perceive aircraft as a threat. Johnson and Todd (1977) found that caribou had habituated to the presence of a highway and vehicular traffic along a traditional movement route. Cutting operations have been common in the NWGSA for the past decade.

*Habitat selection*

Woodland caribou, unlike barren-ground caribou and reindeer, may use forested habitat extensively throughout the year (Shoesmith and Storey 1977; Fuller and Keith 1981; Darby and Pruitt 1984; Brown 1986). Mature coniferous forests are recognized as a major component of summer habitat (Stevenson and Hatler 1985; Brown *et al.* 1986; Servheen and Lyon 1989).

Woodland caribou tend to use a greater diversity of habitat types during the summer than at other times of the year (Darby and Pruitt 1984). Female caribou in the NWGSA used all habitats in proportion to their availability the summer before a clearcut was made. Habitat use by those females that were not displaced by clear-cutting was comparable to that reported in northern Alberta (Fuller and Keith 1981). Woodland caribou in Alberta frequented black-spruce muskeg most heavily at all times of the year (44% of all locations) with black-spruce forest second in frequency (14%). Female caribou displaced by clear-cutting in our study area selected mature forest, and avoided burned and hardwoods habitat where they would have been more visible. Johnson and Todd (1977) observed that woodland caribou in British Columbia approached highways with caution and took cover in nearby timber when approached.

*Sex and age ratios*

Females and young calves are more easily alarmed by, and more likely to flee from, a potential threat than are males, barren females, or females with older calves (de Vos 1960; Lent 1966; Bergerud 1974; Curatolo 1975; Roby 1978). Human disturbance, particularly activity associated with northern oil development, has recently been implicated in altered sex and age ratios within caribou populations (Cameron *et al.* 1979; Cameron and Whitten 1980). Dau and Cameron (1986) reported a local displacement of maternal caribou during the calving period in response to roads and associated activity in Alaska.

Our sex- and age-ratio classifications suggest that females, specifically those with calves, avoided clear-cut areas. Males appeared less sensitive to disturbance, and accounted for most (68%) of the animals classified along the NWGRS. Hanson (1981) noted that bull caribou displayed greater acceptance of buried-pipeline berms than did cows and calves.

We observed low calf:cow ratios near the NWGRS during summer, but significantly higher ratios on the herd's wintering grounds. This suggests that maternal females avoided clear-cut areas near the NWGRS during summer. Roby (1978) reported low cow:calf ratios near pipelines and roads in Alaska. Similarly, calf numbers, as a proportion of the total, observed from road systems within the Prudhoe Bay oilfield and the Trans-Alaskan Pipeline Corridor have been substantially lower than regional values determined from aerial surveys (Cameron *et al.* 1979; Cameron and Whitten 1980).

The response of radio-collared maternal versus nonmaternal females to clearcuts was impossible to assess because we lacked complete information on reproductive status. However, 3 of 10 females displaced by clear-cutting were known to have calves. They shifted an average of 14.1 km compared with 8.5 km for seven females of unknown reproductive status. Of the 10 females not displaced by clear-cutting, only two were known to have calves. The 2 females that moved towards clearcuts were barren and moved only 1.9 ($P = 0.02$) and 2.7 km, respectively, ($P = 0.04$) closer to clearcuts.

Four of seven radio-collared males initially located near clearcuts did not move significantly during cutting operations.

Previous studies have also characterized adult male caribou as being more tolerant of human activity (Curatolo 1975; Roby 1978; Hanson 1981; Whitten and Cameron 1983; Dau and Cameron 1986).

## Acknowledgements

Financial and logistical support for this study were provided by: the Government of Newfoundland and Labrador, Department of Environment and Lands (Wildlife Division); Wildlife Habitat Canada; Abitibi–Price Company Ltd.; and the Department of Wildlife Ecology, College of Agricultural and Life Sciences, University of Wisconsin, Madison. We thank J. Blake, J. Graham, A. St. George, and B. Tucker for field assistance, and our pilot G. E. Ploughman. J. R. Cary provided software used in movement analyses, programming, and statistical advice. Logistic support from field and office staff of the Newfoundland Wildlife Division is gratefully acknowledged.

Afoldi, T. T. 1978. Introduction to digital images and digital analysis techniques: a basic course for the appreciation of digital analysis of remotely sensed multispectral data. Energy Mines and Resources Canada. Remote Sensing. Tech. Note No. 78-1. Ottawa.

Alldredge, J. R., and Ratti, J. T. 1986. Comparison of some statistical techniques for analysis of resource selection. J. Wildl. Manage. **50**: 157–165.

Allen, G. M., and Barbour, T. 1937. The Newfoundland wolf. J. Mammal. **18**: 229–234.

Banfield, A. W. 1974. The relationship of caribou migration behavior to pipeline construction. *In* The behavior of ungulates and its relation to management. *Edited by* V. Geist and F. Walther. Intl. Union for Conservation of Nature and Natural Resources, Publications, Morges, Switzerland. pp. 797–804.

Banfield, C. E. 1983. Climate. *In* Biogeography and ecology of the island of Newfoundland. *Edited by* G. R. South. Monogr. Biol. **48**: 37–106.

Bergerud, A. T. 1974. The role of the environment in the aggregation, movement, and disturbance behavior of caribou. *In* The behavior of ungulates and its relation to management. *Edited by* V. Geist and F. Walther. Intl. Union for Conservation of Nature and Natural Resources, Publications, Morges, Switzerland. pp. 552–584.

Boer, A. H., Redmond, G. and Pettigrew, T. J. 1989. Loran-C: A navigation aid for aerial surveys. J. Wildl. Manage. **53**: 228–230.

Brown, W. K. 1986. The ecology of a woodland caribou herd in central Labrador. M.Sc. thesis, Department of Environmental Studies, University of Waterloo, Waterloo, Ont.

Brown, W. K., Huot, J., Lamothe, P., Luttich, S., Paré, M., St. Martin, G., and Theberge, J. B. 1986. The distribution and movement patterns of four woodland caribou herds in Quebec and Labrador. Rangifer, Spec. Issue No. 1. pp. 43–49.

Cameron, R. D., and Whitten, K. R. 1980. Influence of the Trans-Alaska Pipeline Corridor on the local distribution of caribou. *In* Proceedings of the Second International Reindeer and Caribou Symposium, Røros, Norway, 17–21 September 1979. *Edited by* E. Reimers, E. Gaare, and S. Skjenneberg, Direktoratet for vilt og ferskvannsfisk, Trondheim. pp. 475–484.

Cameron, R. D., Whitten, K. R., Smith, W. T., and Roby, D. D. 1979. Caribou distribution and group composition associated with construction of the Trans-Alaska Pipeline. Can. Field-Nat. **93**: 155–162.

Cumming, H. G., and Beange, D. B. 1987. Dispersion and movements of woodland caribou near Lake Nipigon, Ontario. J. Wildl. Manage. **51**: 69–79.

Curatolo, J. A. 1975. Factors influencing local movements and behavior of barren-ground caribou (*Rangifer tarandus granti*). M.Sc. thesis, Department of Wildlife and Fisheries, University of Alaska, Fairbanks, Alaska.

Curatolo, J. A., and Murphy, S. M. 1986. The effects of pipelines, roads, and traffic on the movements of caribou, *Rangifer tarandus*. Can. Field-Nat. **100**: 218–224.

Damman, A. W. H. 1964. Some forest types of central Newfoundland and their relation to environmental factors. For. Sci. Monogr. No. 8.

Damman, A. W. H. 1983. An ecological subdivision of the island of Newfoundland. *In* Biogeography and ecology of the island of Newfoundland. *Edited by* G. R. South. Monogr. Biol. **48**: 163–206.

Darby, W. R., and Duquette, L. S. 1986. Woodland caribou and forestry in northern Ontario, Canada. Rangifer, Spec. Iss. No. 1. pp. 87–93.

Darby, W. R., and Pruitt, W. O., Jr. 1984. Habitat use, movements and grouping behavior of woodland caribou, *Rangifer tarandus caribou*, in southeastern Manitoba. Can. Field-Nat. **98**: 184–190.

Dau, J. R., and Cameron, R. D. 1986. Effects of a road system on caribou distribution during calving. Rangifer, Spec. Iss. No. 1. pp. 95–101.

De Vos, A. 1960. Behavior of barren ground caribou on their calving grounds. J. Wildl. Manage. **24**: 250–258.

Dixon, K. R., and Chapman, J. A. 1980. Harmonic mean measure of animal activity areas. Ecology, **61**: 1040–1044.

Edmonds, E. J. 1988. Population status, distribution, and movements of woodland caribou in west central Alberta. Can. J. Zool. **66**: 817–826.

Edmonds, E. J., and Bloomfield, M. I. 1984. A study of woodland caribou (*Rangifer tarandus caribou*) in west central Alberta, 1979 to 1983. Alberta Energy and Natural Resources, Edmonton, Alta.

Fuller, T. K., and Keith, L. B. 1981. Woodland Caribou population dynamics in northeastern Alberta. J. Wildl. Manage. **45**: 197–213.

Hanson, W. C. 1981. Caribou (*Rangifer tarandus*) encounters with pipelines in northern Alaska. Can. Field-Nat. **95**: 57–62.

Horejsi, B. L. 1981. Behavioral responses of barren ground caribou to a moving vehicle. Arctic, **34**: 180–185.

Johnson, D. R., and Todd, M. C. 1977. Summer use of a highway crossing by mountain caribou. Can. Field-Nat. **91**: 312–314.

Klein, D. R. 1971. Reactions of reindeer to obstructions and disturbances. Science (Washington, D.C.), **173**: 393–398.

Klein, D. R. 1980. Reaction of caribou and reindeer to obstructions—a reassessment. *In* Proceedings of the Second International Reindeer and Caribou Symposium, Røros, Norway, 17–21 September, 1979. *Edited by* E. Reimers, E. Gaare, and S. Skjenneberg. Direktoratet for vilt og ferskvannsfisk, Trondheim. pp. 519–527.

Klein, D. R. 1991. Caribou and the changing North. Appl. Anim. Behav. Sci. **29**: 279–291.

Lent, P. C. 1964. Calving and related social behavior in the barren-ground caribou. Ph.D. thesis, Department of Zoology, University of Alberta, Edmonton, Alta.

Lent, P. C. 1966. Calving and related social behavior in the barren-ground caribou. Z. Tierpsychol. **6**: 701–756.

Mech, D. L. 1983. Handbook of animal radio-tracking. University of Minnesota Press, Minneapolis, Minn.

Miller, F. L., and Gunn, A. 1979. Responses of Peary caribou and muskoxen to helicopter harassment. Can. Wildl. Serv. Occas. Pap. No. 40.

Miller, F. L., Jonkel, C. J., and Tessier, G. D. 1972. Group cohesion and leadership response by barren-ground caribou to man-made barriers. Arctic, **25**: 193–202.

Murphy, S. M., and Curatolo, J. A. 1987. Activity budgets and movement rates of caribou encountering pipelines, roads, and traffic in northern Alaska. Can. J. Zool. **65**: 2483–2490.

Neu, C. W., Byers, C. R., and Peek, J. M. 1974. A technique for analysis of utilization–availability data. J. Wildl. Manage. **38**: 541–545.

Roberts, B. A. 1983. Soils. *In* Biogeography and ecology of the island of Newfoundland. *Edited by* G. R. South. Monogr. Biol. **48**: 107–162.

Roby, D. D. 1978. Behavioral patterns of barren-ground caribou of the Central Arctic Herd adjacent to the Trans-Alaska oil pipeline.

M.Sc. thesis, Department of Wildlife and Fisheries, University of Alaska, Fairbanks.

Rominger, E. M., and Oldemeyer, J. L. 1989. Early-winter habitat of woodland caribou, Selkirk Mountains, British Columbia. J. Wildl. Manage. **53**: 238–243.

Servheen, G., and Lyon, L. J. 1989. Habitat use by woodland caribou in the Selkirk Mountains. J. Wildl. Manage. **53**: 230–237.

Shoesmith, M. W., and Storey, D. R. 1977. Movements and associated behavior of woodland caribou in central Manitoba. *In* Proceedings of the XIII International Congress of Game Biologists, Atlanta, Georgia, 11–15 March, 1977. *Edited by* T. J. Peterle. Atlanta, Ga. The Wildlife Society, Washington, D.C. pp. 51–64.

Smith, W. T., and Cameron, R. D. 1983. Responses of caribou to industrial development on Alaska's Arctic Slope. Acta Zool. Fenn. **175**: 43–45.

Smith, W. T., and Cameron, R. D. 1985. Reactions of large groups of caribou to a pipeline corridor in the Arctic Coastal Plain of Alaska. Arctic, **38**: 53–57.

Stevenson, S. K., and Hatler, D. F. 1985. Woodland caribou and their habitat in southern and central British Columbia. Studies of radio-collared caribou in the Spatsizi Wilderness Area, British Columbia, 1980–1984, Spatsizi Assoc. for Biological Research. Rep. No. 3, Wildlife Rep. No. R-12.

Valkenburg, P., and Davis, J. L. 1985. The reaction of caribou to aircraft: a comparison of two herds. *In* Proceedings of the First North American Caribou Workshop, Whitehorse, Yukon, 28–29 September, 1983. *Edited by* A. M. Martell, and D. E. Russel, Whitehorse, Yukon. Can. Wildlife Serv. Spec. Publ., Ottawa. pp. 7–9.

Valkenburg, P., Boertje, R. D., and Davis, J. L. 1983. Effects of darting and netting on caribou in Alaska. J. Wildl. Manage. **47**: 1233–1237.

White, G. C., and Garrott, R. A. 1990. Analysis of wildlife radio-tracking data. Acedemia Press Inc., San Diego, California.

Whitten, K. R., and Cameron, R. D. 1983. Movements of collared caribou, *Rangifer tarandus*, in relation to petroleum development on the Arctic Slope of Alaska. Can. Field-Nat. **97**: 143–146.

Zar, J. H. 1984. Biostatistical analysis. 2nd ed. Prentice-Hall, Englewood Cliffs, Nj.